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# Recent Breakthroughs in VHF Interferometry

A.S. Cohen,[1] W.M. Lane,[1] N.E. Kassim,[1] T.J.W. Lazio,[1] R.A. Perley,[2] W.D. Cotton,[2] J.J. Condon,[2] and W.C. Erickson[3]
[1]*Remote Sensing Division*
[2]*National Radio Astronomy Observatory*
[3]*University of Tasmania*

**Introduction:** The NRL-National Radio Astronomy Observatory 74 MHz (4-m wavelength) receiver system on the Very Large Array (VLA) telescope (an array of 27 25-m radio antennas located in Socorro, New Mexico) has, for the first time, demonstrated the capacity for both high sensitivity and high angular resolution observations in the VHF band. A number of instrumental, algorithmic, and computational advances have allowed us to compensate for the ionospheric phase corruptions that have made high-resolution imaging a challenge at such a long wavelength until now. This project has turned the VLA, previously a centimeter-wavelength instrument, into the world's most capable meter-wavelength instrument, in which we regularly achieve resolutions as small as 150 microradians. This capability has enabled us to embark on many scientific projects. It has also spawned plans for building even more capable long-wavelength instruments such as the Long Wavelength Array (LWA), which an NRL-led collaboration is now developing. In this article, we describe two of the many projects now ongoing: the VLA Low Frequency Sky Survey, and probing even higher resolutions by extending the 74 MHz receivers to the nearby Pie Town (New Mexico) station.

**The VLA Low Frequency Sky Survey (VLSS):** The VLSS is a 74 MHz survey of the entire sky visible from the VLA (3/4 of the total sky). It will reach an average sensitivity level of 0.1 Jy/beam (1 Jy = $10^{-26}$ W $Hz^{-1}$ $m^{-2}$), and a resolution of 400 microradians. Ionospheric phase distortions are corrected using a grid of celestial sources to provide multiple simultaneous pierce points through the ionosphere and determine ΔTEC corrections at the level of 10 milliTEC units. Once a region is imaged, we use an automated source-finding algorithm to catalog all sources detected with at least 5-sigma certainty. We are releasing all data to the public as soon as it has been reduced and verified. These data are available on our project website (http://lwa.nrl.navy.mil/VLSS) in the form of a searchable source catalog and a postage stamp image server. Our first major data release occurred on June 15, 2004; it consisted of approximately half of the visible sky. We plan to observe most of the remaining area in early 2005 and release the data online later that year. This resource, available to the entire scientific community, expands the growing virtual online observatory to this previously unavailable wavelength.

Figure 4 shows the current survey area and plots all 32,000 detected sources. Figure 5 shows images of a representative sample of sources that are large enough to be resolved at this resolution.

Several scientific goals can be addressed with these data. A primary goal is the detection of high redshift (very distant) radio galaxies, which this survey is ideally suited for. These radio galaxies are relatively more luminous at long wavelengths than nearby galaxies. We will also use these data to search for diffuse emission in clusters of galaxies (cluster halos and relics) that results from cluster collisions and mergers, and can help our understanding of structure formation in the early universe. It may also be possible to find unusual classes of pulsars, such as those with submillisecond periods or those that reside in binary star systems. We will likely be able to map supernovae remnants and regions of neutral hydrogen gas throughout the galactic plane. Many known objects will be better understood with the knowledge of how their overall spectral index evolves at this long wavelength. Finally, this comprehensive data set will allow us to construct a long-wavelength sky model that is vital to the design of the next generation of long-wavelength telescopes such as the LWA.

**Probing Higher Resolutions with the Pie Town Link:** For long-wavelength astronomy to reach its full potential, it must reach similar resolution to that achieved with centimeter-wavelength observations, or about an order of magnitude more than that which the 74 MHz VLA is now capable. For this reason, the next generation of long-wavelength radio telescopes, such as the LWA, will require interferometric baselines lengths up to 500 km. The main difficulty with this is that no one has ever been able to remove the ionospheric phase corruptions on such long baselines with the precision necessary to achieve the desired resolution across the full field of view.

The NRL team has recently taken a first step toward this goal by expanding the 74 MHz system on the VLA to include an antenna from the Very Long Baseline Array (VLBA) located at Pie Town, New Mexico. Using the Pie Town Link, a fiber-optic connection that allows this antenna to function as if it

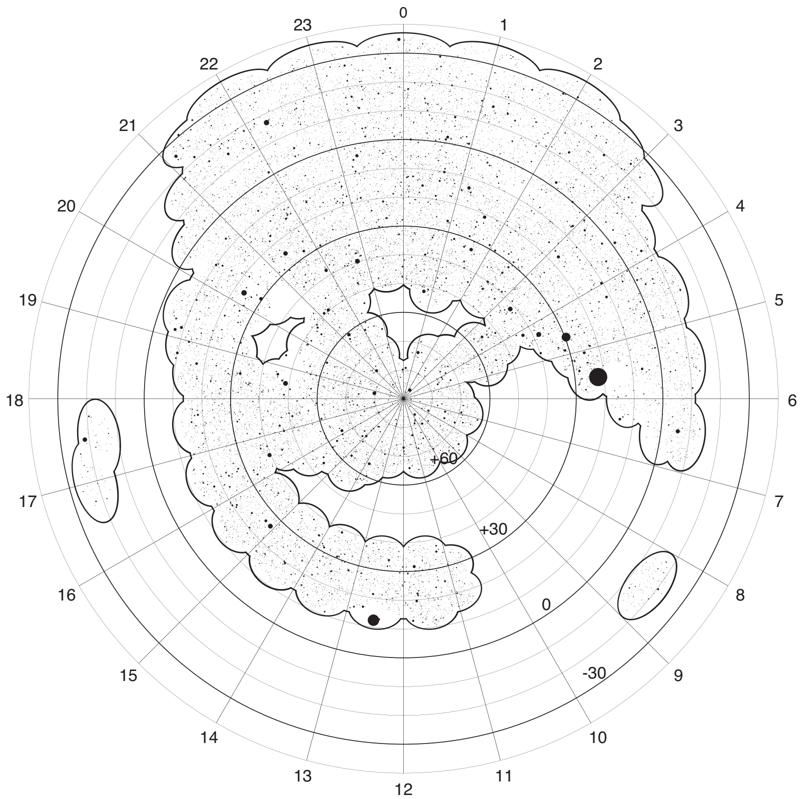


**FIGURE 4**
Current status of the VLSS. Over 32,000 sources have been detected and about half the visible sky imaged. Close-up maps and source catalogs are available in our first data release (http://lwa.nrl.navy.mil/VLSS). Sources are plotted with dots, with diameters proportional to the square roots of their measured flux densities.

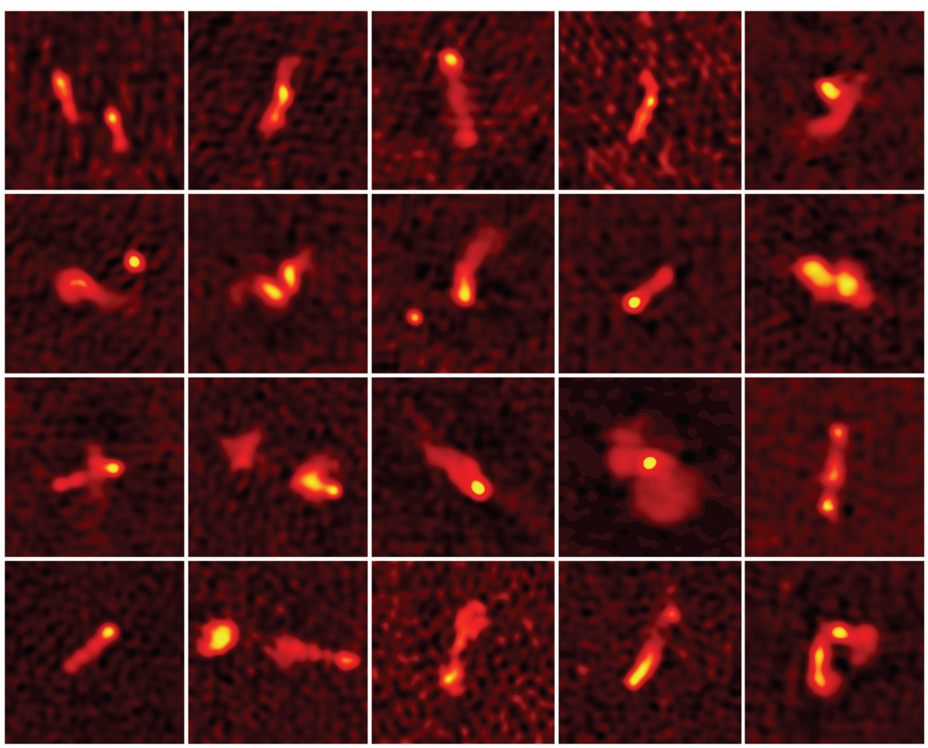

**FIGURE 5**
Close-up maps of a sample of VLSS sources that are large enough to be resolved at this frequency. Each map is 6 milliradians across.

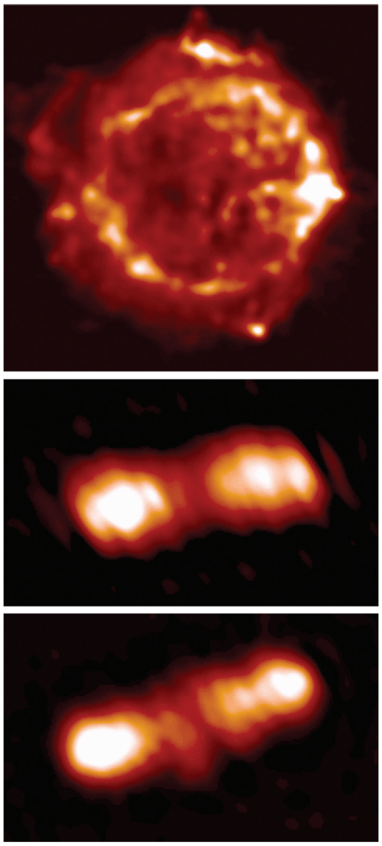

**FIGURE 6**
Recent 74 MHz Pie Town Link images of Cassiopeia A (top, Ref. 1), Hercules A (middle, Ref. 2), and Cygnus A (bottom).

were part of the VLA, the maximum baseline length is expanded from 35 km to 73 km. Completed just last year, we have successfully used this system to observe several bright astronomical objects at a full theoretical angular resolution of ~60 microradians. Figure 6 shows some of the recent images produced with this system. Scientifically, this has allowed us to probe the fine-scale spectral properties of a variety of sources. Technically, we have doubled the longest baseline over which ionospheric phase distortions have been properly calibrated at this frequency, bringing us closer to the baseline scales of future meter-wavelength instruments.

[Sponsored by ONR]

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